

## Approaches to study biological systems at PAL-XFEL

PAL-XFEL operates user beamtime for various scientific studies related to physics, chemistry, and biology since 2017. It especially provides XFEL pulses in a very high quality for the timing jitter and stability [1, 2]. To unveil the macromolecular structures at room temperature and nearly atomic resolution, we run the serial femtosecond crystallography (SFX) science program at the NCI experimental station that delivers high-density photons with K-B mirror optics. We have developed and facilitated various sample delivery techniques to deal with a small sample consumption and complex configuration for the time-resolved studies [3, 4]. According to the sample characteristics and purpose of the experiment, we provide specific instruments to deliver micro-crystals. The crystal delivery techniques can be categorized into liquid flow and fixed target systems.

For the liquid flow scheme, the carrier matrix delivery (CMD) injector is used for the highly viscous media requiring high pressure to put the crystals to the X-ray interaction point. On the other hand, micro-liter volume (MLV) syringe injector can be applied to the relatively lower viscous samples. The MLV syringe injector is also available to perform time-resolved SFX experiments accompanied with multiple optical pump lasers simultaneously. On the other hand, the fixed target (FT) system has a good advantage of simple and stable operation during the crystal delivery process. We have developed two kinds of FT systems, 2D and 1D configurations [5, 6]. The 2D FT system is composed of a mesh and two thin films to keep the hydrated condition and reduce crystal falling due to the gravity during the scanning. To pursue a decrease in sample consumption, the 1D FT system has been developed, which utilizes microtubing to contain micro-crystal slurries. It also has a strong point to handle the samples while maintaining humid environment. In addition, we are under development for other instruments to provide more opportunities to the users regarding time-resolved studies based on domestic and international collaborations.

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